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CUSHIONING THE RECIPROCATING PARTS OF STEAM ENGINES.*

DISCUSSIONS

By CHARLES E. EMERY and JOHN W. HILL.

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CHARLES E. EMERY.—I was requested, some time since, in the usual way, to discuss this paper at the Convention, and must confess, that in examining it for that purpose I was very much disappointed. There was an opportunity for some one with sufficient information and leisure to so investigate and discuss this subject as to include all known conditions and present formulæ and conclusions of value to others in the profession. I am sorry to say that this has not been done in the paper in question. Some quotations are made from standard works, but the original discussion commences by announcing a quotation for a mathematical analysis to show apparently the relative values of V_1 and V, representing respectively the cost of the power in the engine with and without cushioning, but instead of proof on the subject, we are informed that "V is

* Paper CLXV, by John W. Hill, Vol. VII, p. 183. July, 1878.

evidently greater than V_1." This is not considered evident at all, but the very point to be proved. In fact the writer of the paper afterwards attempts to prove it by the arithmetical solution of a special problem not connected with the mathematical notation, without endeavoring to show that the result is a general one, and would not be different for a change of conditions.

The paper concludes as follows: "The writer is of the opinion that the cushion should be adjusted to realize the highest economy with the least reduction of cylinder capacity."

It could equally well be said that the supply of grease to the engine should be adjusted to realize the highest economy in the use of grease, with the least reduction of the power of the engine, but at the same time it would naturally be expected that a few words would be added, explaining the principles upon which the adjustments should be made to secure such economy; or that sufficient facts would be stated to enable the greasers to draw conclusions of their own on the subject.

The principal considerations relating to the subject of cushioning may be briefly stated as follows: Evidently the clearance spaces* at each end of a steam cylinder must be filled at every stroke with steam at the maximum pressure admitted. This may be done in two ways, viz., by admission of steam directly from the boiler or by closing the exhaust passage before the end of the stroke, so that the back pressure vapor will be compressed and the clearance spaces filled with cushioned steam equal as nearly as practicable to the initial steam pressure in cylinder. In the first case the cost is the quantity of steam taken from the boiler to fill the clearance spaces, and in the second, the quantity of steam required in that particular engine to do the work of compression—supposing the net power furnished to be the same in each case. Generally the second plan will have the advantage, for the reason that the steam required to furnish the aditional power will be worked expansively. There can be no economy of steam by cushioning when there is no expansion, and the full theoretical economy due to cushioning is not attained unless the steam is expanded down to the back pressure where the compression begins, which is undesirable on account of the losses due to interior cylinder condensation during extreme

* This term is intended to include the clearance proper as well as the passages and other spaces between the valve and the piston at the end of its stroke.

expansion.* Hence in practice it rarely occurs that the energy absorbed in cushioning is entirely utilized during the return stroke.† Again, cushioning is an indirect operation so the economy resulting therefrom should be charged with a portion of the friction of the engine, since the total load is increased for the same net load. Cushioning also increases the average back pressure, which under certain circumstances, may be a disadvantage. Moreover, in balancing advantages, it should be borne in mind that if there be no cushion the steam in clearances taken directly from boiler would do some work in an expansive engine. All these, and other conditions, must be fully considered to ascertain accurately the economy of cushioning, and until some one takes the time to formulate them, the common sense view must prevail that cushioning is in general productive of a small economy of steam; that at least it causes no loss within the limits available with ordinary valve gear, and therefore may be used to any practical extent to produce desired mechanical effects. In practice the question of economy becomes of secondary importance compared with the mechanical advantages, particularly for high speed engines. Engineers accustomed to stationary engines with governor cut-off, also some marine engineers, have a habit of finding fault with the distribution of steam in the cylinders of a locomotive, and the writer of the paper shows the same disposition by criticising parties who are apparently using similar features on a stationary engine. The indicator diagrams do not look well judged by ordinary theoretical standards, but when all conditions are considered, both theoretical and practical, the true *scientific* result is reached and the valves and gears are found to be very nearly perfect for the purpose. The introduction of the link motion on locomotives over twenty-five years ago immediately produced a remarkable saving in repairs, due greatly to a reduction of shocks in the connections by cushioning, which with the remarkable simplicity of the mechanism, caused its general adoption. The points most criticised are really advantageous for the following reasons: All locomotives necessarily have cylinders proportioned to the adhesion, so as to start the trains and surmount the grades, and such cylinders are altogether too large for the ordinary work, particularly with passenger trains.

* See article on Compound and non-Compound Engines. Trans. Vol. III, p. 368, § 6.

† The paper states (p. 186): "Theoretically there is no loss of power by this process (cushioning), as the energy absorbed in cushioning the steam is given up when the piston begins the opposite stroke." The expression "begins," &c., is faulty, but the idea intended to be conveyed is a popular view which is in general incorrect, as explained.

By "linking up" the cushioning and expansion are both increased and the former, as well as the early release act efficiently to reduce the effective size of the cylinder without requiring the cut-off to be made too short for economy. The early release also permits the escape of the steam at high speeds.

The action of the link motion is due, of course, to the lap valve, and it should not be forgotten that the proper proportions of such a valve were ascertained from numerous experiments by Mr. D. K. Clark, and published in his "Railway Machinery," before the link motion was fairly introduced in this country, and that, consequently, the continual tinkering with the valves practiced on some roads is almost entirely inexcusable. On one very prominent road the passenger engines are actually running with ¾-inch lap, and the only excuse given for it is that the trains had got heavy, and that they had to cut the lap down in order to let the men run in the same notch as before, and upon asking why not leave the lap and hook down further, they really appeared to think that in that way they would use more steam than with less lap and the lever further back. Fortunately, such proceedings are an exception on most roads.

A prominent engine builder once put trip cut-offs in the steam chest cover of a locomotive, the engine being run with links down. No economy resulted, and I was consulted, so the builder, instead of trying to persuade the master mechanic to allow him to cut the lap off the main valve as he intended, sent the apparatus to the scrap heap. I would not have it understood that there is no chance for improvement in locomotives, only that certain criticisms are unfounded when all things are considered. The valves are getting so large that it will pay to balance them when an arrangement sufficiently simple is found. Where fuel is dear, feed water heaters with part of the exhaust steam (requiring larger boilers on account of reduction in draft) will come into use, and a simple combined lever and screw reversing gear thus happen to be adopted on roads when the master mechanic is the inventor. The greatest successes for a long time will be due to good proportions and careful management.

For condensing engines the lap valve and link motion also have advantages that are not duly appreciated. The power required is so nearly uniform that the inside lap can be regulated to give the release exactly as desired, and the extreme cushioning due to comparatively

short points of cut-off is hardly noticed on account of the low back pressure, and is, moreover, advantageous in producing smoothness of working and screening the interior of the cylinder for a portion of the stroke from the refrigerating influence of the condenser through the exhaust steam.*

JOHN W. HILL.—It is, or should be, apparent to Mr. Emery that the locomotive is not under consideration in the paper, for locomotives, as a class, are not engines that run at uniform speed. Whilst variable cushion, by reason of variable speed, is necessary in the locomotive engine, excessive cushion (compression) to reduce cylinder capacity is not sought; and the best practice in locomotive valve motion at the present time makes the inside or exhaust lap just sufficient to insure a closure of both steam parts when the slide valve is at mid travel; as a consequence, the closure of the exhaust is made as late as possible with a given position of the link.†

If the slide valve and link motion were capable of such an effect the power of the locomotive engine and capacity of cylinder could be sufficiently varied by shifting the links with constant exhaust closure, and were locomotive engines to operate at constant speed, Mr. Emery would no doubt agree with the writer that a constant compression should obtain, however great the disagreement might be upon the amount of cushion for given initial pressure, speed and weight of reciprocating parts.

Variable compression in the locomotive engine is desirable, and the variation (other conditions the same) should be as the square of the speed; but it is not pretended that this condition is met in the locomotive valve gear, for with any position of link and initial pressure, the speed will vary between widely separated limits, depending upon the load and plan and profile of track.

The steam diagram of maximum economy, so far as the compression line affects it, is when the compression to initial pressure is had with least reduction of cylinder capacity; but in engines working steam at five or more expansions, the reduction of cylinder capacity to obtain compression to the initial pressure is a very large percentage of the total cylinder capacity, and in a practical point of view, is scarcely justified

* See paper on "Steam Engine Economy," Transactions, Vol. VII, page 63.

† Tests of a Baldwin Locomotive. Journal of the Franklin Institute, April and May, 1879. Dimensions of Engine and Diagrams.

by the resulting economy of performance, as compared with the economy to be obtained by a reduced cushion with an increased effective capacity of cylinder. Hence the opinion expressed by the writer at the close of the paper.

It is well known to steam engineers that compression in steam engines is material to the economy of performance, and that it is of sufficient importance to be well understood. That it is not so understood is well proven by the literature upon the subject. The only intelligent consideration of the problem that the writer is familiar with being by Mr. Charles T. Porter, and his views, while elegant in theory, are incapable of demonstration, by reason of his neglect of conditions subsisting in steam cylinders in practice, in that he assumes no pressure, or what is the same, a constant pressure upon the steam side of piston at exhaust closure, when, in fact, this pressure is subject to a wide range, and an adjustment of cushion by Mr. Porter's formula must fail in realizing desired results.

ERRATA.

Transactions American Society of Civil Engineers. Vol. IX, January, 1880. Inter-Oceanic Canal Projects, by Walton W. Evans. Page 20, third line from bottom: instead of fifteen *metres* to the mile, read fifteen *inches* to the mile.